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Strangers In A New World: The Problem of Exotic Organisms in Saskatchewan

Fish and Wildlife Technical Report 01-3

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Strangers In A New World: The Problem of Exotic Organisms in Saskatchewan

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Abstract

The problem of exotic species in Saskatchewan is reviewed by first providing a global overview of the issue. The present situation in Saskatchewan is then reviewed with respect to aquatic, grassland and boreal ecosystems. The pathways along which exotics find their way into the province are highlighted with particular emphasis on biotechnology, biological control, horticulture and game farming. Both federal and provincial legislation that relates to exotic species is reviewed. Recommendations are provided with respect to monitoring and research, management, cooperation, legislation and education.

1) Monitoring and Research

- Establish policy positions within government dealing with exotic invasive species
- Conduct research on, and monitor, exotic invasive species distributions and dispersal
- Locate pathways of entry into the province
- Establish and document ecological impacts

2) Management

- Focus equally on controlling and limiting known pathways and population control
- Take a proactive approach to exotic species
- If possible, control natural dispersal into the province
- Use a system of adaptive management to provide for adjustment of control measures
- Work with other key agencies, industries and governments

3) Cooperation

- Create channels of communication between all stakeholders
- Establish common goals for the control of exotics
- Discuss and coordinate control measures among stakeholders

4) Legislation

- Work with the federal government to extend WAPPRIITA to cover more than just endangered species
- Work with the federal government to consider a 'white list' approach to exotics
- Change *The Wildlife Act* to cover all species of exotics and not just vertebrates
- Require environmental assessment for the release of new exotic species
- Apply and enforce current legislation regarding exotics to its full extent

5) Education

- Prepare and distribute educational materials concerning exotics
- Work with industry to promote the use of native species

Introduction

Increasing human population, per capita consumption and mobility have led to the expansion of global trade. Around the world, this increase in global trade has also resulted in unprecedented invasions by non-native species. These biological invasions can produce severe, irreversible impacts on natural resources. Invasive species threaten biodiversity, habitat quality, ecosystem function and ultimately, our own welfare. The threat from invasive species is ranked by most conservation biologists as the second most important factor contributing to the decline of natural ecosystems and their associated biodiversity. This report was commissioned in order to shed some light on the present and potential distributions and impacts of exotic invasive species in Saskatchewan.

Background

A) Definitions

For the purposes of this paper, the following definitions have been utilized:

1) Introduced/non-native/exotic/non-indigenous/alien species: Organisms that have evolved elsewhere and have been deliberately or accidentally relocated by humans.

2) Invasive species: Those species which are able to spread and prosper in areas where they have not occurred before.

3) Native/indigenous species: Organisms that occur within within a particular area or region.

4) Transgenic/genetically modified organisms (GMOs): Organisms in which genetic material has been transferred by human manipulation from another species.

5) Naturalized exotic: Introduced species that have become established and are maintained by natural reproduction; not necessarily invasive.

6) Biological invasion/bioinvasion: The spread of alien, exotic organisms into areas where they do not naturally occur.

7) Ecosystem integrity: A condition where the function and structure (including genetic, species, and ecosystem diversity) of an ecosystem are unimpaired by human-induced stresses.

8) Biological diversity/biodiversity: All species of plants, animals and microorganisms and the ecosystems and ecological processes of which they are a part.

B) A Global Overview

"We must make no mistake: we are seeing one of the great historical convulsions in the world's fauna and flora." (Elton 1958).

The tendency to spread exotic species is a deeply embedded and universal aspect of human culture. For thousands of years, people all over the world have employed exotics for both necessity and pleasure. The human propensity to move exotic organisms beyond their native ranges goes back far into our past. For example, aboriginal peoples planted corn (*Zea mays*), native to Central America and Mexico, in the Great Lakes region long before the arrival of European colonists. In early Roman times and perhaps until the end of the Roman Empire in Europe, Common Carp (*Cyprinus carpio*) were introduced into central and western Europe for culture in ponds as food. Goldfish (*Carassius auratus*) were brought from Asia to Europe as an ornamental species at about the same time (Courtenay 1993). From the beginning, fish culture was also accompanied by escapes into natural waters, for example, by both carp and goldfish. Exotic species have thus been a feature of human history. However, there is a significant difference between the regional low level pressure from exotic species in the past and what has happened in the last 50 years as the process has become greatly globalized. The spread of exotics is now perceived by many ecologists to be one of the greatest threats to biodiversity, and is thought to rank second only to habitat destruction (Wilcove et al. 1998). In certain instances, exotic invasion is the principle threat. For example, during the past century in North America, exotic species have been a factor in 68% of native fish extinctions (Bright 1998). In addition, bioinvasion is exacerbated by habitat destruction. As more and more habitat is ploughed up, burned, bulldozed, or cut down, the remnant natural areas grow ever more vulnerable to invasion by exotic species.

Today, the ability of exotic plants, animals and pathogens to move around the world is unprecedented. Previously, the physical variety and structure of the Earth tended to hold its living communities in place. These natural barriers have been instrumental in the evolution of species suited to a particular piece of land, stream or lake. Some degree of movement around these physical barriers has always been a part of life on Earth, but the movement of species today differs fundamentally from natural range extensions in at least three respects (Bright 1998):

1) The frequency of movement - Under natural conditions the arrival of a new species to most areas was a rare event. Today, new species are establishing at a rate that is hundreds to thousands of times higher than the natural rate.

2) The pervasiveness of movement - In the past, major ecological changes occasionally allowed mixing of plants and animals between physically close regions. Today, intense mixing of species is a widespread global phenomenon.

3) 'Impossible migration' is now not only possible but common - Under natural circumstances, physical boundaries have always imposed formidable boundaries to the movement of organisms. For example, certain drainage basins limited the movement of aquatic organisms. Today, the movement of organisms across these natural barriers is routine. As far as we know, this is without precedent in the entire evolutionary history of life on Earth.

Invasion by exotic species is one of the few types of environmental degradation that can degrade virtually every level of biological organization. For example, at the ecosystem level, plants like Crested-wheat grass (*Agropyron cristatum*) can affect fundamental ecosystem functions like the flow of energy and nutrients in prairie soil (Christian and Wilson 1999). Most commonly, invasive exotics impact native species by either killing them (i.e., predator, parasite, disease, etc.) or by out-competing them for resources (e.g. light, nutrients, food, nest places, etc.; Williamson 1996). At the other end of the spectrum, interbreeding between native and exotic species can be thought of as a 'genetic invasion' that undermines the native gene pool (Williamson 1996).

The proportion of exotics that cause serious problems is difficult to estimate, but a rough 'rule of thumb' is that 10% (varies by organism group from 5-20%) of exotics introduced into an area will succeed in establishing breeding populations and of these, 10% will go on to launch major invasions (Table 1). In other words, 1% of the arriving species will go on to cause major ecological and economic damage. Other studies suggest that 1 in 7 exotic species will create problems (Simberloff 1996). When this happens, it is because the exotic has escaped the predators, disease and competitors that kept its numbers in check in its native landscape. There is little consolation in the fact that 90 percent or more of all exotics turn out to be benign, since we are continually bombarding our ecosystems with new non-native species.

Despite over 40 years of study, ecologists have not been able to develop any hard and fast predictive rules that govern the process of invasion. We do not know which invaders will become successful invaders. No common characteristics have been detected. Many of the worst invaders are highly adaptable 'generalists', but there are successful 'specialists' too. Some invasive species have close relatives that are also detrimental while others have relatives that are not at all invasive. For example, among the estimated 60 species of dandelions only one is a serious weed in North America. From over 100 species of buckthorn only two are considered a pest (Wagner 1993). We do not know where bioinvasions will occur. For the most part, highly disturbed species-poor ecosystems are more vulnerable to invasion but there are exceptions to this (Stohlgren et al. 1998). We do not know when invasions will occur as many exotics take several tries before they succeed in establishing themselves. For example, some exotic plants have an 'incubation period' whereby they spend decades as innocuous members of the plant community before some subtle adaptation or ecological shift triggers an major invasion (Figure 1). Most importantly, we seldom know what an invader will do until after the fact and thus, there is considerable capacity for surprises. A good example of this is the ability of Zebra Mussels (*Dreissina polymorpha*) to shut down nuclear power plants operating on the Great Lakes by clogging water intake pipes and valves. In addition, whenever one introduces a new species, one is also introducing some or all of the diseases, pathogens and parasites that are associated with it. For example, Common Carp (*Cyprinus carpio*) have been shown to harbour up to 138 species of exotic parasites (Bright 1998). As a result, the only hard and fast rule of exotics is: "The strongest predictor of negative impacts of a non-indigenous organism remains whether it has had negative impacts in other areas to which it has been introduced." (Daehler and Gordon 1997). If an exotic is causing trouble elsewhere, then it is wise not to further spread it.

Table 1: The tens rule in British angiosperms.

	Number	Percentage
Total Imported	12507	
Total casual or more	1642	13.1
Total established	210	12.8
All pests	39	18.6 (of 210)
Severe pests	14	6.7 (of 210)
From Williamson 1996.		

Figure 1: Spread of European Mustard into Eastern Canada and the United States, 1860 - 1990

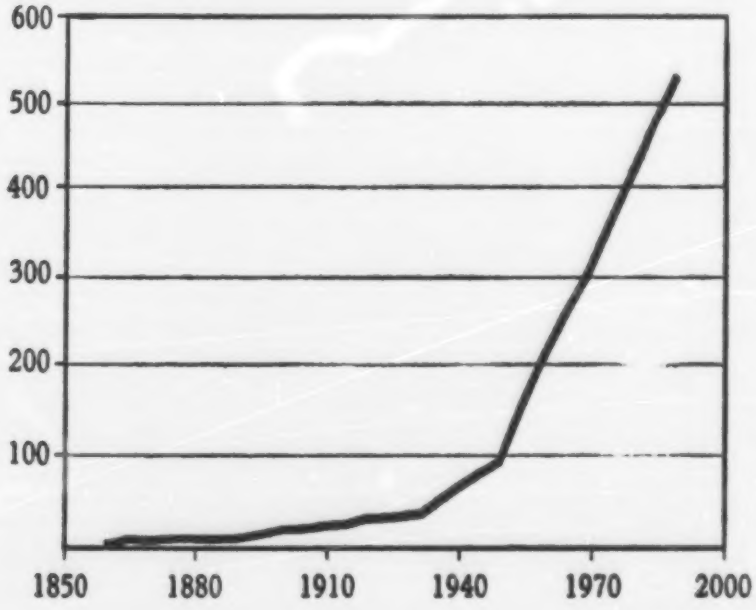

FIGURE 1. *Spread of European Mustard into Eastern Canada and the United States, 1860–1990*

(from Bright 1998)

In addition to ecological damage, biological invasion also threatens us with major economic costs. Even so, less work has been done regarding the economic costs of introducing non-native species compared to the ecological costs. Almost all of the economic calculations have come from the United States. In 1993, the Office of Technology Assessment (a research branch of the U.S. Congress) reported baseline estimates for the economic damage caused by 79 major invasions into the U.S. during the last century as US$97 billion. More recently, researchers at Cornell University calculated that exotic animals, plants and microbes in the U.S. cost US$123 billion per year. In general, one does not blame the patient for the disease, but in this instance, our global economy is not a passive victim of the exotics that are damaging it. Exotic plants and animals are often introduced for their expected economic benefits, and this economic activity is responsible for most of the damage that has been caused by them. For example, there is the tendency to try to capitalize on 'managed invasions' through the planting of exotic forage crops for livestock. One of the few attempts to quantify the costs and benefits of this activity is a 1994 survey of forage plant introductions in Australia. Of the 466 species introduced, only 21 turned out to have some actual merit for the livestock industry. 60 species were definitely invading rangeland, including 17 of the 21 potentially useful plants. Only 4 of the introductions were beneficial and non-invasive. Estimates from the study were that the Australian ranching industry gained marginal profit from the introductions (at the rate of $2 per hectare), while the general public covered the substantial control expenses (at $30-$120 per hectare; Bright 1998).

Of all the forms of environmental degradation, biological invasion may be the most difficult to overcome. In general, the key to dealing with environmental problems like habitat destruction or pollution is stopping or reducing the offending activity. Of course, this is usually no easy task. Nevertheless, with time and thoughtful management, natural ecological processes can often heal a damaged ecosystem. Time alone, however, will not often heal the effects of biological invasion. Even after an intense invasion peaks and subsides after depleting most of the local resources, it does not mean that the exotic will disappear. It may rebound after resources recover, it may spread elsewhere, or it may simply adapt to the new conditions. Rather than diminishing over time, invasive organisms usually entrench themselves (Coblentz 1990).

C) Saskatchewan: An Overview

In Saskatchewan, little research has been directed at the impacts and pervasiveness of exotic species. However, many comparisons can be drawn from research done on exotics in other regions with similar ecosystems and problems. This section will consider the greatest exotic threats to our native biodiversity in the three major ecosystems of Saskatchewan: wetlands, grasslands and forests. The threats identified here are by no means an all-encompassing list of provincial exotic species' problems, but they do illustrate some of the most pressing issues.

1) Aquatic Ecosystems

The movement of potentially invasive fishes and other aquatic organisms in North America continues to increase at an alarming rate (Courtenay 1993). Those who purposefully move and introduce non-native aquatic organisms often claim that there has been relatively little environmental damage demonstrated from such releases. Of course, not all fish introductions will be bad, but every introduction will result in

impacts to native biota, which may range from almost nil to major (including extinctions) with time (Figure 2). No natural aquatic system (or other ecosystem) can accept a non-native species without change (Coutenay 1993). With aquatic biota, however, these impacts are more difficult to notice, observe, and measure than in more familiar terrestrial habitats. In Saskatchewan and the rest of North America, millions and perhaps billions of dollars have been, and are, expended by agencies and industry to import, culture and directly introduce exotic fishes; yet very little money is spent to examine pre- or post-introducion impacts. Quite often, those who introduce fishes deliberately are more interested in impacts on fishes considered immediately useful to humans and not to the overall native fish fauna or ecosystem biota.

Most introductions of exotic fishes into Saskatchewan have stemmed from the desire to introduce potential sport fishes. Most are typically high-level predators that have a high capacity to impact the populations of aquatic organisms at lower trophic levels. Because we know so little of the natural workings of our native aquatic ecosystems, most potential impacts are based on presumptions as to their cause and effect (Bright 1998); that is, because the changes were not seen, determined and measured while they were occurring, we assume little effect. Testing expected impacts prior to making an introduction is a far safer and more worthwhile approach than has characterized our history of fish introductions in the province. There are 58 known species of native fishes. A total of 23 exotic fish species have been introduced into the province over the last century. Currently, 11 species of exotic fishes are thought to occur in Saskatchewan waters (K. Murphy, pers. comm.). Based on these numbers, the proportion of established exotics is very high when compared with other regions in North America. Of all our ecosystems, the aquatic ecosystems are probably the most heavily affected by exotics. However, we have little information regarding the impacts of these introductions on native aquatic biodiversity. There is some indication, though, that the effects of introductions into some aquatic systems have been enormous. For example, recent test netting in Last Mountain Lake indicated that exotic Common Carp constituted the majority of fish biomass in the lake. In 1998, catches from trap nets at the south end of the lake yielded 20,000 Common Carp and only 20 Bigmouth Buffalo (*Ictiobus cyprinellus*) (K. Murphy and R. Hlasny, pers. comm.). It is believed that the population explosion of Common Carp in Last Mountain Lake has had a direct impact (through competition) on the decline of the Bigmouth Buffalo in the lake. As a result of this (along with other factors), the Bigmouth Buffalo is soon to be listed as an endangered species in the province.

Figure 2: Native and Introduced Fishes in Clear Lake, California 1880-1980

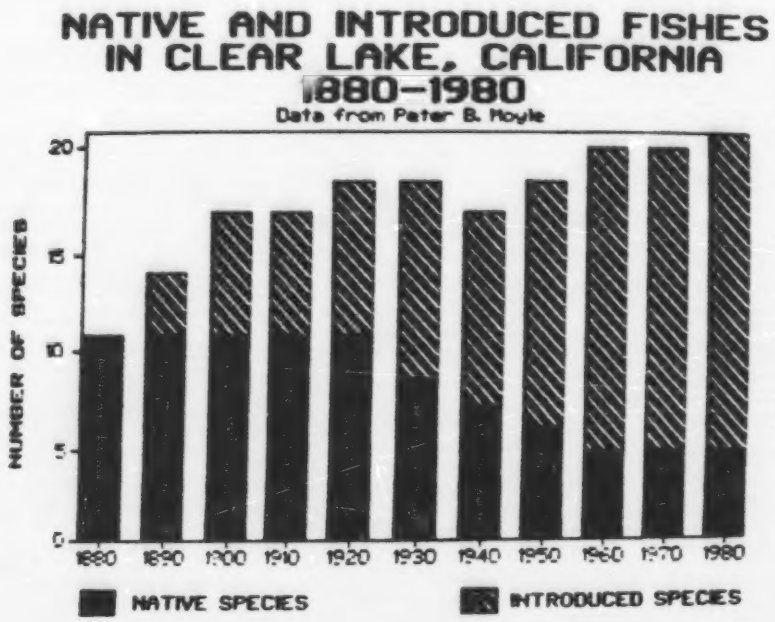

Figure 2: Effects of introductions on biodiversity of native fishes in a lake with few other environmental perturbations (from Courtney 1993).

Another problem involves the transfer of fish from different parts of their range. This is very common in fisheries management throughout North America and is, of course, a form of genetic invasion of the fish that have evolved in particular regions. The net result is the compromise of the locally-adapted gene complexes of the resident fishes. In Saskatchewan, the transfer of Walleye (*Stizostedion vitreum*) has been investigated at the genetic level and its mitochondrial DNA was found to be similar throughout the province. Therefore, the within-province movement of Walleye is probably acceptable and safe.

To date, most releases of invasive species in the province have been from intentional sport fish introductions. However, aquaculture, if not properly regulated, represents perhaps the greatest source for future introductions of invasive fishes and fish diseases into North American waters, including our own (Courtenay and Williams 1992). Aquaculturalists are attracted by species of foreign origin, possibly thinking that they will provide higher financial returns because of the 'mystique' of marketing something different. Some of the potential problems associated with aquaculture such as nutrition, disease, parasites and water quality can be easily dealt with. A more significant challenge, however, is how to prevent escape or deliberate release into open waters. Aquaculture uses natural stocks of organisms that have the potential to survive on their own should they escape or be released elsewhere. The ideal situation might be to ensure either triploidy, or preferably sterilization, of all but the brood stock (Courtenay 1993).

Finally, there is also a large threat from various aquatic weeds such as Purple Loosestrife (*Lythrum salicaria*) and exotic invertebrate species that are currently expanding their ranges from the Great Lakes region. The most serious of these is probably the Zebra Mussel which has made its way into the Missouri River System, probably by 'hitchhiking' on boating equipment. It is just a matter of time until it arrives in Saskatchewan. Zebra Mussels are detrimental to native molluscs through direct competition and extremely costly to remove from infrastructure such as intake pipes and pumping stations, etc. They multiply at an incredible rate; a single female may release thousands of eggs per year. They will completely encrust any available surface and when they run out of room, they will encrust each other.

2) Grassland Ecosystems

Over the last 100 years, our native grasslands have been heavily modified by agriculture and for the most part, people in the southern portion of the province live in a vast artificial 'prairie' of domesticated exotic grasses. With the success of these edible grasses, though, has come the success of numerous exotic insects, weeds and pathogens. Throughout the history of settlement on the prairies, there has been a prevailing philosophy of remedying the symptoms of poor land management rather than the causes (Romo and Grilz 1990). The literature suggests that exotic plants and arthropods present our grassland regions with the greatest threats to biodiversity and ecosystem integrity. Many exotic plants in the south have become established by deliberate introduction with the idea of increasing forage production. Unfortunately, we have little data (mostly a few anecdotal reports) regarding the spread of many exotic plants into native adjacent grassland areas in the province (however; the Conservation Data Centre, SERM is currently compiling data on the distributions of exotic plants). For arthropods, recent research on native grasslands has shown that 12 out of 157 beetle species were exotic (Pepper 1999). Even though there is limited data on the invasions of arthropods and plants in the grassland region, some general conclusions can still be drawn.

The dynamics of exotic invasion in the south is a permanent feature of large scale agricultural disturbance in the province. The grassland region contains so many potential sources of disturbance to both the agricultural landscapes and to the adjacent native ones that the prospect for long-term stability is low. There are several dimensions to this instability from the perspective of an exotic species. First, the boundary between many crops and 'weed' species is 'porous'. Most crops are members of 'complexes' (groups of closely-related species) with similar habitat requirements that can often interbreed. For example, all 12 species in the oat genus, *Avena*, will interbreed, including domestic oats and wild oats. This interbreeding may allow a newly introduced crop variety to pass some of its genes on to the crop's undesirable relatives (genetic invasion). This may allow an invasion by exotic hybrids into areas where they have not occurred before. Secondly, several exotics may act together and their movement between agricultural and native prairie can produce results that are damaging to both ecosystems. There are many exotic plants and several exotic arthropods that belong under this scenario. One interesting exotic plant that is prevalent in both agricultural and native grassland areas is Smooth Brome (*Bromus inermis*; Romo and Grilz 1990). Smooth Brome is native to southern Europe but has been widely introduced into Canada for forage production and erosion control, beginning in the late 1800s. The greatest invasions of Smooth Brome appear to be in moister areas of short grass and mixed prairie, as well as aspen parkland regions (Romo and Grilz 1990). Little attention appears to have been paid to controlling Smooth Brome in natural areas because this grass is widely used in agriculture. Driver (1987) found that as the age of brome-dominated grasslands increased, its use by native birds declined from 8-10 species to 2. Other work has shown that exotic vegetation influences native bird communities by causing a change in the species' composition (Wilson and Belcher 1989). The final factor involving grassland exotics is that they are adapting and changing at a rate that is much faster than the 'background' rate. This is due to the heavy use of pesticides and herbicides in our grassland agricultural regions which has put enormous selection pressures on the invertebrates and weeds that are targeted. Unfortunately, all that has really happened is that we have created resistant strains of exotic pests that are now better competitors and even harder to eradicate than when they first arrived.

3) Boreal Ecosystems

The boreal forest region of the province is currently impacted by a number of human factors as a result of economic development. This includes activities such as oil and gas exploration, mining, and forest harvesting and their attendant road-building. In terms of exotics, invasion of our forests at the present time are mostly limited to small herbaceous plants (e.g., Canada Thistle, *Cirsium arvense*). However, there are large potential invasions looming just over the horizon. For example, plantation style or 'agroforestry' has the potential to cause ecological damage to our forests in the same way as agriculture has done to our native grasslands. Another major area of concern is the potential invasion of exotic forest pests and diseases.

Plantation style or agroforestry for commercial production of short rotation woody crops has been in development in the southern hemisphere for about the last 40 years. Between 1965 and 1990, tropical plantation forestry area increased five to sixfold and most of the countries involved have announced plans to double their plantation areas by 2010 (Bright 1998). North America is presently well behind in the development of agroforestry. Tree plantations in general are seen as something of a paradox; despite the planting of billions of trees, they have been implicated with the destruction of natural forests and the establishment of exotic species (Bright 1998). Most plantations are monocultures, and like any

other monoculture, they require intensive management (i.e., inputs of fertilizer, pesticides and herbicides). Quite often, exotic trees or hybrid crosses of exotic and native trees are seen as a panacea to agroforestry. From a biological invasion standpoint this potentially is of considerable concern. If exotic trees are used then there is the possibility that they might become invasive. The use of hybrid plants increases the threat of a 'genetic invasion' (i.e., through crossbreeding with native species; Williamson 1996). Genetic considerations are important not only in the effect of invasions, but also part of the reason for the success of some invasions and the failure of most. For invasions, the conclusion from the best studies available is that the critical difference between success and failure will often come from differences centered around 10 or fewer genes (Williamson 1996, Quetin et al. 1995).

Native forest insects are an important part of the cycle of forest renewal and thus an integral part of the boreal ecosystem. The spread of exotic forest insects is a growing threat to Canada's forests (Canadian Forest Service 1999). In the past century, they have caused substantial effects on forest health and biodiversity in different regions (Canadian Forest Service 1999). Insect and pathogen exotics are probably the biggest threat in terms of invasive species in the province. A recent arrival in Canada and one of potential concern to Saskatchewan is the Asian Long-horned Beetle (*Anoplophora glabripennis*). The beetle arrived in wood used as packing material for Asian imports. This beetle is well established in the U.S. and has already been the target of control campaigns in New York and Chicago where millions of dollars have been spent to cut down thousands of infected trees (Canadian Forest Service 1999). Of particular concern to Saskatchewan is that the beetle attacks poplar (*Populus* spp.) plantations in China. If this beetle makes its way to Saskatchewan the results could be disastrous for our aspen forests. Another exotic beetle of potential concern is the Eight Spined Spruce Bark Beetle (*Ips typographus*). This spruce beetle is one of the most serious pests of spruce in its native range in Europe and Asia (Humphreys and Allen 1999). Adults have been detected in British Columbia, Ontario, Quebec, New Jersey, Indiana and Pennsylvania. It prefers to attack mature stands of spruce and it is thought that all spruce stands across Canada are at risk. The beetle is also a known vector of several fungi that are pathogenic to conifers (Humphreys and Allen 1999). Although many of the exotic pests and diseases listed by the Canadian Forest Service are not known to occur in Saskatchewan at this time, shifts in global climate, increased human disturbance and movement and other factors could enable a number of pests to invade our province's forests at great ecological and economic cost. At this time, there is no estimate for Saskatchewan or Canada of timber losses due to invasive species in our forests (Canadian Forest Service 1999). Losses due to exotic forest pests in the United States are estimated to be about US$4 billion annually (Pimentel et al. 1999). Of course, this does not include the significant costs to native forest biodiversity.

D) Pathways of Exotics into Saskatchewan

The global economy, including the movement of goods, products and services is the ultimate factor driving the spread of exotic species around the Earth. It appears to be a universal feature of human culture to provide 'pathways' to convey organisms far beyond their natural ranges. These pathways can be found in almost every economic industry in the province including agriculture, forestry, horticulture, interprovincial and international trade, fish and wildlife introductions, mining, oil and gas development, and the pet trade. In addition, organisms can invade our province on their own from adjacent jurisdictions if they are not being controlled there. Our biopollution problems cannot be isolated to any one particular industry or human activity. Of course, some species are more likely to arrive here, either intentionally or accidentally, through certain pathways. Below is a more detailed examination of the invasion risks from four important pathways.

1) Biotechnology

One of the most powerful trends in agriculture today involves the rise of biotechnology; essentially techniques for manipulating genes and moving them from one species to another, often very different species. Genetic engineering can be used to make organisms with new properties that may be commercially useful (Williamson 1996). In crop plants, herbicide and pest resistant varieties are being developed. In principle, any commercially desirable trait can be added or enhanced. Of course, like any technology, there are costs and potential risks involved. Will there be any ecological hazards from genetically engineered organisms? Russo and Cove (1995) provide a good overview of the benefits and hazards of this technology. For a newly genetically engineered organism, all environments are new, and therefore one would predict similar problems to other exotic species. The proponents of the technology maintain that for commercial genetic engineering, the 'invasion model' is not appropriate. For example, they suggest that crop plants are familiar, new varieties will have to undergo extensive performance trials, and the genetic novelties are more precise and better understood than strains produced by traditional methods. The release of genetically engineered plants is therefore different from other invasions. The unsatisfactory points to this argument are covered extensively by Williamson (1996). Although the crop plant is familiar, and the genes inserted are well known, the combination is novel. The literature on biological invasions suggests that there are virtually no universal characters that distinguish exotic weeds and pathogens from their harmless relatives and that genetic differences between invasive species and non-invasive ones may be very small. In fact, many plants have become weeds merely by being taken to a new region. Thus, it is not surprising that many ecologists believe that aspects of the invasion model are relevant to the risk assessment of genetically engineered organisms (Williamson 1996). Even where there is regulation through small scale trials, the study of plant invasions suggests that the probability of detecting undesirable effects under short term research is not large given that many exotic plants have taken decades to invade and may still be expanding their ranges despite control measures. At the other end of the spectrum, some invaders were recognized as problems almost immediately but spread so fast that it was impossible to limit the damage. Since any genetically engineered organisms that become problems will be commercial products, they will likely be widespread and thus difficult to control whether the problem arises sooner or later.

2) Biological Control

There are many types of biological control, but all basically focus on using biological agents to control undesirable species. Biocontrol almost always involves a predator, parasitoid or pathogen. Two very different types of biological control are classical and inundative (Williamson 1996). Under classical biological control, the undesirable species is normally an arthropod or plant pest that attacks crops and does so partly because it has been released without its natural enemies, and thus has reached a high population density. The strategy under classical biocontrol is to search the region of origin for suitable enemies, grow them in quarantine (to rid them of their enemies) to test their host range and then to release those species that are approved. The intention is to establish one or more control species that will reduce the pest at no further cost. Ideally both pest and control agent will then persist at low densities.

Inundative control uses a control agent as if it were a chemical pesticide, spraying it on the pest and getting a rapid kill (Williamson 1996). *Bacillus thuringiensis* is a native bacterium that produces a protein that is toxic to insects and is often used in this way. The advantage over ordinary chemicals is that the agent is usually more specific and shorter lived. However, claims that it only attacks lepidopteran pest species are clearly false. Pure inundative control does not usually involve the establishment of new species (although it could), but strategies falling between inundative and classical usually do.

Biological control is often put forward as entirely safe with no ecological implications and so much preferred to chemical control. It can at times be brilliantly successful, but has also been shown to be disastrous or more often pointless (Bright 1998, Williamson 1996). In fact, evidence suggests that most releases of biocontrol organisms fail to establish control on the target pest at all (Table 3). There is also considerable concern as to how safe biological control is (Samways 1994, Simberloff and Stilling 1996). The main issue is how often arthropod control agents attack non-target species. For example, one native species became extinct because the biocontrol agent was able to make use of an alternate host. Thus, a control agent used for controlling an agricultural pest that also has a few 'victim' species could eliminate some while still maintaining itself on the target pest species. This appears to have happened in New Zealand and Hawaii (Williamson 1996). Therefore, the potential for biocontrol agents to impact desirable native species is always a possibility.

In summary, the only demonstrably safe biocontrol agents are those that are completely species specific. Poorly thought out use of a biocontrol agent amounts to the same effect as using "anthrax to control overgrazing by sheep" and the damage is almost guaranteed to be permanent.

3) Horticulture

Despite it being a fairly minor industry, horticulture has been responsible for releasing some of the world's worst plant invaders (e.g., Purple Loosestrife, *Lythrum salicaria*; Bright 1998). One survey of 1,060 woody plant invasions from all over the globe found that in 624 cases in which the origin of the invasion could be ascertained, 59% came from botanical gardens, landscaping or other similar purposes. In North America, garden introductions are estimated to account for about 50% of the 300 or so serious pest plants in natural areas (Binggeli 1996). Many species that are known to be invasive are still being sold. In fact, more than 60% of North America's worst weeds are still being sold by nurseries (Bright 1998). Plant breeders are also continually combing the genome of established garden plants for new varieties. In addition to escaped garden plants, horticulturalists release a large number of exotic insects, such as lady bugs. In Saskatchewan, *The Horticulture Society Act* virtually guarantees the release of new invasive plants into the province (see below).

4) Game Farming

The threats to Saskatchewan from game farming mostly center on the importation of exotic ungulates into the province. There is the possibility that these animals can escape and some may become invasive. However, it is more likely that some exotic ungulates will hybridize with our native species (e.g., European Red Deer with Elk, *Cervus elaphus*). Game farming also brings with it the possibility of establishment of exotic diseases and parasites when exotic animals are brought into the province. In this way, game farming is no different than any form of agriculture dealing with the domestication and use of exotic species.

Federal Legislation and Exotic Species

1) *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act* (WAPPRIITA), *1996*

WAPPRIITA is the tool by which Canada fulfills its obligations under the Convention on the International Trade of Endangered Species of Wild Fauna and Flora (CITES). The Act makes it an offence to import wildlife products that have been illegally obtained or illegally exported from other countries. WAPPRIITA also protects Canada from the introduction of exotic or non-native species that may be harmful to indigenous species. WAPPRIITA is now used to designate 'harmful' species formerly listed in the Customs Tariff or under the Export and Import Permits Act. Enforcement of WAPPRIITA is overseen by the Enforcement Branch of Environment Canada. Under Section 5 of the Act, agreements may be made with provinces or territories to provide for cooperative management and administration of the Act and to avoid duplication in federal and provincial regulatory activity. Such an agreement has been reached with Saskatchewan through a Memoranda of Understanding (MOU) completed in 1997. Under the MOU, Saskatchewan is responsible for issuing permits and leading enforcement activities related to the export of all indigenous species listed by CITES. In addition, Saskatchewan is obligated to look after the interprovincial transport of exotic or non-native species designated under WAPPRIITA (by cross reference with provincial legislation) as being harmful to Canadian ecosystems. The exception to this is for those species for which Department of Fisheries and Oceans holds responsibility.

2) Department of Fisheries and Oceans *National Policy on Introductions and Transfers of Aquatic Organisms* (2000 draft)

This draft policy focuses on minimizing the negative impacts of intentional introductions of non-native species and the transfer of species outside their normal ranges. It applies to all live aquatic organisms covered by *The Fisheries Act* (federal) and covers all activities such as aquaculture, commercial and recreational fishing, aquarium rearing and research and ecological control programs. It is also applicable to fresh water plants and invertebrates which provide elements of fish habitat. The intent of this proposed policy is to create a risk assessment process such that introduction and transfers of aquatic organisms will, or may be, permitted only when any potential risks or negative impact is clearly determined to be low or minimal. The risk assessment process is mainly accomplished through Introduction and Transfer Committees in each province or region by the agency or agencies responsible for administering fisheries or aquaculture.

3) *Plant Protection Act, 1990*

This Act is written to protect plant life and the agricultural and forestry sectors of Canada by preventing the importation, exportation and spread of certain pests and by controlling or eradicating pests in Canada.

4) *The Health of Animals Act, 1990*

This Act pertains to diseases and toxic substances that may affect animals or that may be transmitted by animals to persons. Thus a particular exotic animal may be allowed into the country but only if it is not carrying one of the listed diseases.

5) *The Seeds Act, 1997*

Currently, the focus of this Act is on the maintenance of crop seed integrity. *The Seeds Act* can be thought of as a weak preventative regulation for invasive species' control; however, it does not address concerns related to established populations. Of the many hundreds of invasive plants, the Weed Seeds Order under the Act classifies only 72 plants species as noxious weeds. For example, Purple Loosestrife is not included on the list.

Provincial Legislation And Exotic Species

1) *The Fisheries Act, 1994*

Under this Act, it is illegal to 'acquire, raise, possess, use, culture, import, introduce, process, package, market, carry or transport any fish or dispose of any fish or allow any fish to be wasted except in accordance with any licence or any provisions of this Act or the Fisheries Act (Canada) or its regulations.' For the purposes of the Act, 'fish' refers to any species of fish and includes any aquatic crustaceans, aquatic molluscs, or aquatic invertebrates, any eggs or sperm from any fish or any part or parts of any fish.

2) *The Wildlife Act, 1997*

Under provisions of *The Wildlife Act*, no person is allowed to import or introduce any wildlife into Saskatchewan without an import licence. Wildlife in this case are defined as "a vertebrate animal of any species, excluding fish that is wild by nature in Saskatchewan..." By restricting itself to vertebrates, the Act omits the majority of other species of exotic animals and plants that have been shown to have detrimental ecological effects.

3) *The Horticultural Societies Act, 1978*

This Act deals with the establishment and operations of horticultural societies within Saskatchewan. It pertains to exotic and invasive plant species in that it deals with the promotion of them within the province. More specifically, Section 10 states: 'the objects of a society shall be to encourage improvement in horticulture, ... by importing and otherwise procuring and distributing seeds, plants, shrubs, and trees of new and valuable kinds.'

4) *The Noxious Weeds Act, 1984*

The Noxious Weed Act deals with any plants that the Agriculture Minister may designate in the regulations as a noxious weed for the purposes of the Act, and includes the seeds of that plant. As of 1999 there are 41 species of noxious plant species listed. Most of them are non-native species.

5) *The Animal Products Act*/Domestic Game Farm Animal Regulations, 1999

Under this legislation, restrictions are placed on individuals regarding the species of animals that may be held in captivity for the purpose of producing products. Under this legislation six non-native large mammals are currently allowed into the province.

6) *The Diseases of Animals Act, 1978*

This Act pertains to the prevention and control of diseases of animals in the province. It relates to non-native animals through The Diseases of Game Farm Animal Regulations, 1999, which would deal with diseases in any of the exotic game farm animals.

7) *The Apiaries Act, 1978*

This Act deals with the possession, import, registration and health of European Honey Bees (*Apis mellifera*). Under *The Apiaries Act*, no person shall import into Saskatchewan, without permission from the Minister, any bees from outside the province. In addition, African Honey Bees (*Apis mellifera adansonii*), Honey Bee tracheal mites (*Acarapis woodi*) and Honey Bee Varroa mites (*Varroa jacobsonii*) are declared 'diseases'.

8) *The Pest Control Act, 1992*

This Act pertains to the control, destruction and prevention of spread of pests. Pests are defined under the Act as any animal, insect or disease that the Agriculture Minister deems likely to be destructive or of danger to any crop, grain, livestock or other property. To date, only four groups of organisms have been declared pests: the Norway rat (*Rattus norvegicus*), Dutch elm disease (*Ophiostoma ulmi or Ceraocystis ulmi*), 'grasshoppers' and the 'warble fly' (no scientific names mentioned for either).

9) *The Forest Resources Management Act, 1996*

A number of references to exotic species are within the Regulations of this Act. For example, 'No person shall introduce, transport, deposit, possess or propagate any noxious weeds as defined in *The Noxious Weeds Act*, 1984 or any exotic plant designated by the minister'. Despite this, 'a person may be granted a licence to conduct research activities involving the introduction and propagation of exotic plants on provincial forest land.'

Synthesis and Recommendations

The evidence is clear that the balance of our natural ecosystems is being impacted by the invasion of exotic organisms. The last century has seen the largest introduction and invasion of exotic species in North America since the 1492-1600 period (McNight 1993). Some have been unintended, but most have been intentional introductions and no region, including Saskatchewan, has escaped. Exotic species are now a common feature of our landscapes and this, in part, is why they have attracted so little attention. For example, southern Saskatchewan is dominated by exotic species and we have become used to living with their presence. In addition, the human lifespan is short compared to the scale of time on which natural systems operate, so that most people cannot perceive these impacts. As a result, we tend to minimize the process of invasion by calling established exotic populations 'naturalized' (e.g., House Sparrow, *Passer domesticus*). However, this is a mistake in that it encourages people to view every invader as simply a native in the making (Bright 1998).

We also tend to view biological invasion as an isolated problem. This, of course, is not so. For example, we know that habitat fragmentation and bioinvasion work together. Less is known, however, on how global climate change will exacerbate the problem of invasive species. Changes in temperature and rainfall patterns are likely to stimulate many new invasions or accelerate invasions already under way. For example, the mild wet winters and dry summers predicted for western North America are likely to favour some of our worst weeds such as Russian Thistle (*Salsola kali*; Cronk-Quentin and Fuller 1995). There is also the possibility that exotic weeds such as Cheat Grass (*Bromus tectorum*) which are currently not a problem will invade the province as our climate changes. Fast growing, highly invasive plants like Cheat Grass may also be able to benefit from the increased carbon content in the atmosphere, whilst slower growing natives, unable to use the carbon as quickly, may tend to lose out to the invaders (Bright 1998). Warmer waters are also likely to invite additional invasions. For example, warm water species may find more room in our province. Because many insects are extremely sensitive to weather patterns, some evidence suggests that they may already be reacting to climate changes (Bright 1998, McNight 1993).

There is little or no chance that the problems asscociated with exotic species will solve themselves within any reasonable time frame without direct intervention. It should also be apparent from the above discussion that invasive species in Saskatchewan, as elsewhere, are tightly bound to our economy and society. Thus, anyone addressing the problem of exotics through policy, legislation and education has to be cognizant of the local or regional 'terrain'. The following is a strategic framework for action with respect to exotic species within Saskatchewan.

1) Monitoring and Research

Currently, there is very little information available on the number, abundance, dispersal, distribution and spread of exotic species in the province. It might be best to begin with well known, extremely detrimental invasives like Leafy Spurge. In any event, the monitoring of exotics should receive at least the same level of concern and staffing that endangered species management does, as the impact from exotics is likely equal or greater than the loss of our native endangered species. In some cases, the two programs could fit together (e.g., Common Carp and Bigmouth Buffalo). As new problem exotics arrive, SERM has to have the ability to track them down. This might allow for their control and eradication if discovered early enough, as exotics are often much more vulnerable in their initial stages of establishment. Overall though, the cheapest solution to controlling invasive exotics is to keep them out if at all possible. In conclusion, we need to:

- establish policy positions within government dealing with exotic invasive species;
- conduct research on, and monitor, exotic invasive species distributions and dispersal;
- locate pathways of entry into the province and
- establish and document ecological impacts.

2) Management

Historically, the response to the arrival and dispersal of invasive exotics has been immediate and thorough when the species in question threatened agriculture; otherwise, the response has been limited. For instance, it is unlawful to introduce, sell, or distribute any unwanted race of honeybee (such as the African Honeybee), but, little or no screening addresses environmental impacts, so non-native species

continue to be allowed entry simply because they pose no danger to established agricultural products and enterprises.

Attempts by government at controlling harmful introductions must be equally focused on controlling the pathways of introduction and achieving maintenance control of existing infestations, especially of the worst offenders (e.g., Common Carp, Leafy Spurge, etc.). This will also include the control of the natural dispersal of exotics from outside the province. Currently, the typical pattern of management in government is reactive rather than being proactive. An ongoing evaluation would provide a continuing source of feedback that would allow for adjustment or abandonment of failing courses of action before a new crisis develops. The management of exotic species by government should be an adaptive process which would incorporate the results of previous actions and adjust future recommendations accordingly. A cycle of data collection, management, evaluation, and analysis would facilitate this approach. In conclusion, we need to:

- focus equally on controlling and limiting known pathways and population control;
- take a proactive approach to exotic species;
- if possible, control natural dispersal into the province
- use a system of adaptive management to provide for adjustment of control measures and
- work with other key agencies, industries and governments.

3) Cooperation

There has to be an increase in the flow of information between branches, departments, governments and industry in terms of exotic species. In some cases, information on exotics (control, distribution, dispersal, establishment) might be available from different branches or different departments within the government. If used in a coordinated manner, this might be able to eliminate or control the spread of a potential or known exotic invasive. For example, the range condition of native grasslands is conducted on some Crown lands by Agriculture and Food and PFRA. In the process, some information is collected on the incidence of exotic plants This information could be shared so that possible strategies for their control can be formulated with other agencies. By the same token, very little information is shared about the release of new genetically modified organisms into the environment. In addition, control efforts of exotic organisms needs to be coordinated among governments and industry in order to be fully effective. In conclusion, we need to:

- create channels of communication between all stakeholders;
- establish common goals for the control of exotics and
- discuss and coordinate control measures among stakeholders.

4) Legislation

Currently, there is a considerable amount of federal legislation in place dealing with the control of exotic species. The shortcomings of the current federal legislation (in particular WAPPRIITA and the *Plant Protection Act*) is that they take a 'black list' approach to exotic species (i.e., a list of undesirable exotics). In addition, WAPPRIITA is really geared to stop the trade in endangered species rather than just exotics. This leaves the door open to any species not on the list and some of these unfortunately will turn out to be invasive. A better approach is the DFO proposed policy on fish introductions and

transfers which puts each transfer and introduction under scrutiny and puts the onus on the proponent to explain why an introduction or transfer will have minimal impact. Even better still would be to take a 'white' list approach and only allow those species which have been shown previously to have minimal impacts on natural ecosystems. All others would be excluded until they had been proven safe. Perhaps if the proponent of an exotic that turns out to be invasive and destructive was forced to pay for ecological and economic damage there would be less enthusiasm for their release.

In terms of provincial legislation, the same 'black list' approach has been taken with many Acts (e.g., *Noxious Weed Act*, *Pest Control Act*, *Disease of Animals Act*) and thus, the same weakness is apparent. Perhaps our strongest provincial legislation in terms of exotic species is *The Fisheries Act*, which is worded so that virtually all aquatic organisms are covered under it. In theory, no one can legally import or introduce any exotic aquatic organism without legal permission. Conversely, *The Wildlife Act* is much weaker than *The Fisheries Act* in terms of terrestrial exotic species. This is because it focuses almost exclusively on vertebrates (except for endangered species). However, as discussed above, the biggest threats from exotic species do not come from vertebrates. The Act should therefore be reworded to cover all terrestrial organisms, and not just vertebrates. This would give SERM the ability to have a say in the importation, introduction and use of any exotic species that now fall outside the legislation. For example, exotic Australian lady beetles were recently released in Regina. Under the current legislation, SERM had no say in this matter, even though ultimately it will have to deal with the consequences should this species become invasive. SERM should also make it a requirement that each introduction undergo a review under *The Environmental Assessment Act*. In summary, we need to:

- work with the federal government to extend WAPPRIITA to cover more than just endangered species
- work with the federal government to consider a 'white list' approach to exotics;
- change *The Wildlife Act* to cover all species of exotics and not just vertebrates;
- require environmental assessment for the release of new exotic species and
- apply and enforce current legislation regarding exotics to its full extent.

5) Education

The simple blocking of pathways will not always work to control many new invasive exotic organisms (e.g., any new exotic garden flowers). What is really needed is a more ecologically literate society that understands the risks, dangers, and costs of introducing exotic species. The common characteristics associated with the promotion of exotics is that "they are hardy, disease free, have few if any insect pests, and reproduce or propagate easily". The message needs to get out that these characteristics are precisely what make exotics species such serious competitors and pests when released into a new ecosystem or habitat. In addition, it needs to be impressed upon the public that the control of exotics is both necessary and cost effective. Any delays in control only serve to raise the price tag later. The obstacle to this is that the benefits of prompt action are often diffuse and difficult to measure, as they are mostly in terms of damage avoided. Government also has to make a greater effort to encourage the use of native species in ecological restoration. Many industries still employ the use of exotics in their restoration work. In the long run, the only real hope against ecological invasion is a public that values species being where they should belong. To summarize, we need to:

- prepare and distribute educational materials concerning exotics and
- work with industry to promote the use of native species.

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